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Effects of Acute Aerobic Exercise on Fat Metabolism in Pre- and Postmenopausal Women of Comparable Body Mass Index

Effekte einer akuten Trainingsbelastung auf den Fettstoffwechsel von prä- und postmenopausalen Frauen mit vergleichbarem BMI

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Summary

- **Problem:** With menopause, the risk of cardiovascular diseases (CVD) increases significantly. A possible molecular mechanism is an estrogen-related change in fat metabolism. Endurance training has been demonstrated to reduce the risk of CVD and to have an impact on fat metabolism (FM). This study aims to analyze the ability of pre- (preW) and postmenopausal women (postW) of comparable body mass index (BMI) to activate their FM during endurance training.
- **Methods:** 12 preW and 12 postW were included. Serum Triglyceride, LDL, HbA1C, estradiol and body composition data were determined. The respiratory quotient (RQ) was determined during moderate 30-minute exercise (60% of the 4 mmol threshold) on an ergometer.
- **Results:** While the BMI of preW and postW was comparable, body fat (BF) (p=0.001), lean body mass (LBM) (p=0.001) and abdominal girth (AG) (p=0.003) were significantly different. Significant group effects could also be identified in HbA1c (p=0.001), cholesterol (p=0.001) and LDL (p=0.000) serum concentrations. RQ decreased during 30 minutes of cycling in preW and increased in postW (p=0.010) over time.
- **Discussion:** The higher AG and BF and the lower LBM demonstrates the change in body composition in postW. An accumulation of fat, especially in the trunk region, goes along with an increase of CVD in postW, even with a normal BMI.
- **Conclusion:** It is evident that postW show altered lipid metabolism compared to preW.

Zusammenfassung

- **Problem:** In der Menopause steigt das Risiko für kardiovaskuläre Erkrankungen (CVD) bei Frauen an. Ein Grund ist der durch die Estrogenabnahme veränderte Fettstoffwechsel (FS). Ausdauertraining kann das Risiko für CVD reduzieren und sich positiv auf den FS auswirken. Das Ziel der Studie ist, es die Fettstoffwechselfähigkeit von prä- (präF) und postmenopausalen Frauen (postF) mit vergleichbarem BMI während einer akuten Ausdauerbelastung zu analysieren.
- **Methode:** 12 präF und 12 postF wurden in die Studie eingeschlossen. Im Blut wurden die Parameter Triglyceride, LDL, HbA1C und Estradiol erhoben. Die anthropometrischen Daten und die Körperzusammensetzung wurde ermittelt. Während 30 Minuten (60% der 4mmol Schwelle) Belastung auf dem Fahrradergometer wurde der Respiratorische Quotient (RQ) erhoben.
- **Ergebnis:** Während der BMI von präF und postF vergleichbar war, unterschieden sich Körperfett (KF) (p=0,001), Magermasse (p=0,001) und Bauchumfang (p=0,003) signifikant. Signifikante Gruppeneffekte konnten auch bei den Serumkonzentrationen von HbA1c (p=0,001), Cholesterin (p=0,001) und LDL (p=0,000) festgestellt werden. Der RQ verringerte sich bei präF und stieg bei postF (p=0,010) an.
- **Diskussion:** Der höhere Bauchumfang und das Körperfett und die niedrige Magermasse zeigen die Veränderung der Körperzusammensetzung. Eine Anhäufung von Fett, vor allem im Rumpfbereich, geht mit einer Zunahme von CVD bei postF einher, auch bei normalen BMI.
- **Konklusion:** Es zeigt sich das postF im Vergleich zu präF einen veränderten Fettstoffwechsel aufweisen.

KEY WORDS:
Menopause, Cardiovascular Risk Factor, Aerobic Training, Metabolism

SCHLÜSSELWÖRTER:
Menopause, kardiovaskuläres Risiko, aerobes Training, Stoffwechsel

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Introduction

Cardiovascular diseases (CVD) are still one of the most frequent causes of death for women worldwide (7). In women the individual risk for this diseases increases significantly with menopause (5). The moment of natural menopause is variable and occur for most women on average around the age of 51 to 52. After menopause, the prevalence for CVD increases significantly. Böhm et al. (4) have evaluated that a rate of 39.0 heart attacks per 100000 women occurs in the age of 45 to 49, but there are 95.1 events per 100000 in the age of 50 to 54 years. Similar data are available for nearly all kinds of CVD and is mechanistically believed to be directly associated with the decrease of estrogen serum concentrations in postmenopausal women (5). A possible molecular mechanism discussed is an estrogen related

Table 1

Body composition.

	PRE-MENOPAUSAL (N=12)		POST-MENOPAUSAL (N=12)		P-VALUE
	M	SD	M	SD	
Age (years)	25.0	3.5	57.7	4.3	0.001
Weight (kg)	67.6	9.1	64.1	4.9	0.378
BMI (kg/m²)	23.0	2.3	23.6	1.3	0.444
Abdominal girth (cm)	76.2	7.4	85.1	5.5	0.003
Fat mass (%)	27.9	3.9	34.0	2.4	0.001
Lean body mass (LBM) (%)	72.9	3.9	65.9	2.4	0.001
Body cell mass (BCM) (%)	27.6	3.2	21.9	1.5	0.001

Table 2

Blood parameters. HbA1C=haemoglobin A1c; TG=triglycerides; CHOL=cholesterol; HDL=high-density lipoprotein; LDL=low-density lipoprotein; [a]=-Mann-Whitney-U-Test; [b]=T-test for independent samples.

	PRE-MENOPAUSAL (N=12)		POST-MENOPAUSAL (N=12)		P-VALUE
	M	SD	M	SD	
Blood sugar [mg/dl]	90.7	4.9	98.7	6.2	0.002[a]
HbA1c [%]	5.1	0.2	5.5	0.2	0.001[b]
TG [mg/dl]	64.6	16.6	80.7	29.5	0.178[b]
CHOL [mg/dl]	162.6	23.3	243.9	36.0	0.001[a]
HDL [mg/dl]	59.5	9.2	72.9	12.5	0.007[a]
LDL [mg/dl]	90.3	18.1	154.2	34.7	0.001[a]

change in the fat metabolism of postmenopausal women (14). In animal experiments (11, 19, 20) and in human intervention studies (15) it could be demonstrated that fat metabolism is directly influenced by 17 beta-estradiol. Therefore, there is need for strategies to treat postmenopausal complains, especially for the prevention of CVD and metabolic diseases. A powerful factor of huge impact on metabolism is physical activity. There are numerous studies demonstrating the beneficial effects of exercise in the prevention and therapy of the metabolic syndrome (13, 16). Risk factors correlated to CVD, like serum cholesterol or the high density lipoprotein/ low density lipoprotein (HDL/ LDL) ratio are negatively influenced by the decrease of estrogens and can be significantly improved by exercise (18). Interestingly, in animal experiments it was shown that a decrease in serum estradiol results in a reduction of movement drive (20). There are indications that this effect also occurs in postmenopausal women (8, 12). So, the decrease of estrogen serum concentrations in postmenopausal women may have a double negative impact on the cardiovascular system a) directly by a modulation of metabolism and b) indirectly via the reduced motivation for movement.

To develop new individualized therapeutic concepts for the prevention of cardiovascular and metabolic diseases in postmenopausal women, knowledge about the mechanisms involved in the metabolic changes during menopausal transition is important. Therefore, it was the aim of this study to investigate the metabolic response of pre- and postmenopausal women of comparable body mass index (BMI) during low intensity endurance training on a bicycle ergometer.

Material and Methods

Preparticipation Examination

Each women completed 3 days of testing. The study has been conducted in line with the ethical principles set up in the Declaration of Helsinki. All participants received detailed oral and written information about the study before inclusion, and all gave written informed consent to participate. Approval for the experimental study was obtained from the Ethics Committee of the German Sport University Cologne.

For inclusion all pre- and postmenopausal women were healthy, non-smoker, had a BMI lower than 25 and were free of performance limited illnesses and metabolic diseases. No participant took any medication that effect fat metabolism. All attending women had no cancer in history. PreW had to show a regular cycle and no pregnancies. All examinations of PreW were planned in the middle of their menstrual cycle. None of the participants were athletes, all performed less than two hours of endurance training per week. Estradiol and FSH were analyzed to ensure that the women were pre- or postmenopausal and not taking hormone supplements. While examination anthropometric parameters were determined. Body composition was measured by bio-electrical impedance analyses using Body Explorer (Kommunikation & Service GmbH, Frankfurt, Germany).

T1

Before training blood serum concentration of cholesterol (CHOL), high density lipoprotein (HDL), low density lipoprotein (LDL), Triglyceride (TG), blood sugar and HbA1c were determined. The participants underwent a lactate threshold test by means of spiroergometric examination according to the Hollmann-Venrath-scheme by using ergoselect 200P (Ergoline GmbH, Bitz, Germany). At rest and after each stage lactate level, heart rate and BORG stage was determined. The load for the second testing day was determined based on the data collected, by using threshold calculation according to Mader.

T2

During 30-minute load at 60% of the 4mmol threshold on the bicycle ergometer, another spiroergometric examination was carried out. Spiroergometric parameters like, RQ, $\dot{V}O_2$ [l/min] $\dot{V}CO_2$ [l/min] and $\dot{V}O_2$ peak ml/(kg*min) was continuously recorded. Furthermore, heart rate was measured and lactate was collected at minute 10, 20 and 30.

Statistical Analyses

The data collected were used to test for normal distribution using the Kolmogorov-Smirnov test. In the case of a normal distribution, the arithmetic mean values were compared with each other using the t-test for independent samples. If no normal distribution was present, the nonparametric Mann-Whitney U-test was calculated. The current version of SPSS (IBM SPSS Statistics Version 24.0.0.0) was used. By using the Levene-test the equality of error variances was checked and variance homogeneity was assumed for a probability of error p>0.05.

Results

Anthropomorphic Data

12 postW (57.7±4.3) and 12 preW (25.0±3.5) finished the study. During the study 2 PreW had to be excluded. The last menstruation of PostW was 5 to 7 years ago. The BMI of both groups was nearly identical (23.0±2.3 premenopausal; 23.6±1.3 postmenopausal), abdominal girth (AG) (76.2±7.4 cm premenopausal;

85.1±5.5 cm postmenopausal), body fat mass (BF) (27.9±3.9% premenopausal; 34.0±2.4% postmenopausal) and lean body mass (LBM) (72.9±3.9 premenopausal; 65.9±2.4 postmenopausal) showed significant differences (table 1).

Metabolic and Cardiovascular Risk Factors:

Differences in blood parameters between preW and postW could be found for all parameters (table 2). Statistically significant differences could be demonstrated for HbA1c (p=0.001), CHOL (p=0.001) and in LDL concentration (p=0.000).

Metabolic Response during Low Intensity Training

Parameters of all participants related to physical performance showed significant differences. The maximum power was 195±35.9 watts in the preW and 119.2±17.6 watts in the postW while performance at 60% of 4mmol lactate threshold was 88.8±27.1 watts in preW and 59.3±13.7 watts in postW (table 3).

Group differences in the lactate serum concentrations during exercise could be detected after 10, 20 and 30 minutes. In the preW lactate increased during the first 10 minutes of exercise, stay constant until 20 minutes and decreased after 30 minutes. In postW, lactate increased strongly during the first 10 minutes of exercise and keeps on these high levels during the completed exercise period (table 4; figure 1).

RQ in rest was not different between both groups and increased strongly in the first 10 min of exercising. Interestingly, in preW after 20 minutes the RQ decreased. In contrast in the postW, there was a constant increase in RQ over the 30-minute load.

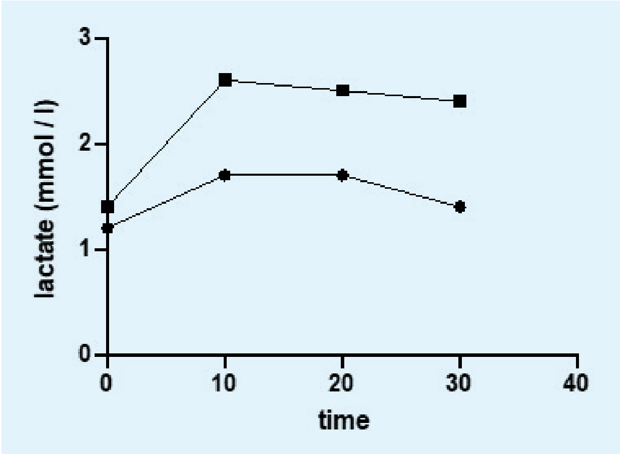

Figure 1

Lactate for 30 minutes endurance exercise. Dots=premenopausal; squares=postmenopausal.

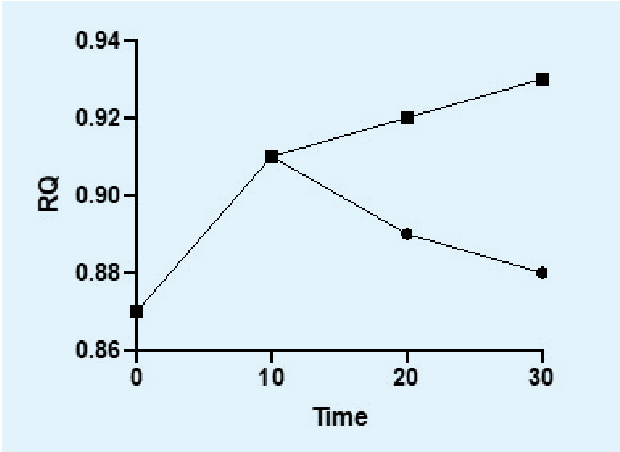

Figure 2

RQ for 30 minutes endurance exercise. Dots=premenopausal; squares=postmenopausal.

Discussion

With menopause, a variety of physiological changes and complaints become apparent in women. With respect to fat metabolism it is of relevance that most women are suffering by weight gain (nearly 0.5kg/year) and abdominal obesity while menopausal transition (10). In our study we investigated preW and postW of comparable BMI (table 1) and a normal body weight. Nevertheless, postW show higher TG, CHOL, and LDL levels at baseline measurement. Interestingly, in postW the measured diameter of AG and BF was significant higher compared to the preW, whereas LBM was significantly lower. This impressively demonstrates the change in body composition in postW although they are per definition of regular body weight. These observations are in line with findings of Chen et al. (6) and Greendale et al. (9) who showed that an accumulation of fat, especially in the trunk region goes along with an increase of CVD in postW, even with a normal BMI. Abildgaard et al. (1) shows that at menopause trunk fat increased while leg fat decreased. We were also able to measure higher AG in the postW, too.

The postW showed significantly higher serum concentrations of blood sugar, HbA1c, CHOL, HDL and LDL compared to the preW (table 2). These results are consistent with other studies. Pu et al. showed higher cardiovascular indicators like triglycerides, LDL cholesterol and fasting glucose in postW (15).

The RQ at rest shows no significant differences between both groups. Exercises results in both groups within the first ten minutes in an increase of the measured RQ (post 0.91±0.03 vs. pre 0.91±0.03), what can be explained by an increased utilization of carbohydrates for energy supply. As expected, the RQ in preW decreases after 20 minutes. This can be explained by an increased utilization of fat as energy supplier, because of the moderate training intensity. This indicates that moderate aerobic exercise results in an increased lipolysis in preW (3). In our postW, even after 30 min no decrease of the RQ was detectable. RQ after 20 min exercise was significantly higher in postW, compared to preW (table 5, figure 2).Even after 30 minutes, energy production in postW seem to delay mainly on carbohydrates (RQ: post 0.93±0.04 vs. pre-0.88±0.04). Since these results are significant, it can be assumed that postW are not able to activate their fat metabolism as an energy supplier when exposed to a 30-minute moderate load, as preW do. These data indicate that the different hormone status seems to have a negative impact, not only on the blood lipid values, but also on the utilization of the fat metabolism during exercise. One explanation could be that estrogens have a direct influence on the mitochondrial membrane and influence bioenergetic function of mitochondria. The lipid tolerability could therefore be influenced by the reduced estrogen level (1, 17). Abildgaard et al. (2) were able to show that postW have higher RQ during a 45-minute exposure compared to preW. Furthermore, postmenopausal women were shown to have 33% lower whole-body fat oxidation. A high whole-body fat oxidation correlated with a low visceral fat percentage. In the data presented here, preW show a lower body fat percentage than postW, according to Abildgaard et al. (2).

Our detected lactate serum concentrations during exercise support these findings. Starting from comparable concentrations in rest in both groups, during exercise lactate serum

Table 3

Parameters related to physical performance.

	PREMENOPAUSAL (N=12)		POSTMENOPAUSAL (N=12)		P-VALUE
	M	SD	M	SD	
Watt max. [Watt]	195.0	35.9	119.2	17.6	0.001
Performance at 60% 4mmol lactate [Watt]	88.8	27.1	59.3	13.7	0.005

Table 4

Lactate for 30 minutes endurance exercise

	TIME	PREMENOPAUSAL (N=12)		POSTMENOPAUSAL (N=12)		P-VALUE
		M	SD	M	SD	
Lactate [mmol/L]	rest	1.2	0.6	1.4	0.3	0.272
	10`	1.7	0.7	2.6	0.8	0.010
	20`	1.7	0.7	2.5	1.0	0.025
	30`	1.4	0.5	2.4	1.1	0.011

Table 5

Respiratory quotient for 30 minutes endurance exercise.

	TIME	PREMENOPAUSAL (N=12)		POSTMENOPAUSAL (N=12)		P-VALUE
		M	SD	M	SD	
RQ	rest	0.87	0.04	0.87	0.05	0.885
	10`	0.91	0.03	0.91	0.03	0.750
	20`	0.89	0.04	0.92	0.03	0.036
	30`	0.88	0.04	0.93	0.04	0.010
RQ [%]	10`-30`	-3.7	4.1	+1.3	4.2	0.011

concentrations increase more significantly in postW (table 4). Lactate is produced as an end product of anaerobic glycolysis. A continuously increase of lactate confirms the increased utilization of carbohydrates as energy sources (2).

In summary the data of our study underline findings demonstrating that estradiol has a huge impact on the fat metabolism (4). Our postW had significantly reduced estrogen levels (post 19.0±0.0 pg/ml vs. pre 134.8±103.4 pg/ml). A decrease in estradiol leads to a reduced fat oxidation rate in animal experiments (11, 19, 29). The results of RQ and lactate values indicate a reduced fat metabolism rate in postW too and thus confirm the influence of estradiol on the fat metabolism of women. This aspect needs to be considered in the development of training concepts for postW. Training concepts need to be depended to the different kinetics in fat metabolism in postW. The recommendations for short (<30 Minutes) moderate aerobic exercise, as a promoter of fat metabolism seems not suitable for women after menopause.

The age effect must be viewed critically. The group of preW was represented by young women (age: 25.0±3.5 years). Thus, the influence of age on the differences in body composition, blood values and stress test data cannot be dismissed.

Nevertheless, our data and findings that there is a deterioration of fat metabolism with decrease of estradiol correspond to those of other authors (1, 2, 3, 5). The influence of age, and thus the difference in performance, can be neglected with regard to the data of RQ and lactate, since the load measurement was carried out based on the individual performance level. According to the differences in performance, differences in the reaction of the fat metabolism were shown.

Conclusion

It seems necessary to develop individualized training concepts accorded on the individual metabolic status and abilities of postW. The data show that postW accumulate more FM and have more harmful blood lipid levels compared to preW at the same BMI. In postW no shift from carbohydrate to fat metabolism was detected via endurance exercise. Therefore, their deficient ability to reach fat metabolism seems to be an important key factor in the development of new training regimes for postW.

Conflict of Interest

The authors have no conflict of interest.

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